Measurements of Density Gradients and Dusty Plasma Rotation in Inductively Coupled Discharges at High Magnetic Fields

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The Dusty Plasma Laboratory (DPL) of the University of Maryland, Baltimore County (UMBC), completed a series of dusty plasma parameter scans at high magnetic fields. Working collaboratively with the Magnetized Dusty Plasma Experiment (MDPX) research group, these experiments were conducted in the superconducting electromagnet at Auburn University (AU). Using external RF antennae to generate inductively coupled plasmas (ICP) in a non-conducting cylindrical vacuum chamber, we show that argon plasma discharges are stable and do not exhibit filaments or arcing in neutral pressures ranging from 5 to 300 mTorr, and magnetic fields ranging from 0 to 3.25 T. The antennae frequency was set between 22 and 30 kHz, resulting in plasma wave cutoff at the vessel wall, and consequently a high plasma density gradient with a maximum at the wall and a minimum at the vessel center. The presence of the magnetic field augmented the density gradient, as plasma diffusion across field lines decreased with increasing field intensity.

Although no probes were immersed in the magnetized plasma to measure density directly, images from two different views were systematically captured during the parametric scan. Using argon atomic emission intensity as a proxy for density (since we expect mostly excited neutrals and singly ionized argon), we estimate plasma density profiles from images, and correlate changes with respect to neutral pressure and magnetic field intensity changes. Our experimental setup used 50 μm diameter silica hollow microsphere dust grains with a wall thickness of about 100 nm. A low power HeNe laser tuned at 652 nm was used to illuminate the dust. Levitation and rotation of the dust were observed in a wide range of pressures and magnetic fields. Video of moving dust was captured at rates up to 100 frames per second, and is being used to measure dust rotation rate and radial range.

The dust grains are too massive to be considered magnetized, but ions and electrons are strongly magnetized. Therefore, dust rotation was likely caused by ion momentum transfer in the azimuthal direction, with ion rotation likely caused by $\nabla P \times B$ drifts in the argon plasma, as was argued by Kaw et al. (P.K. Kaw, et al., Phys. Plasmas 9, 387 – 390), in explaining a previous experiment by Sato et al. (N. Sato, et al., Phys. Plasmas 8, 1786 – 1790). We compare our rotation measurements with the Sato et al. data, up to 1 T (the maximum field they used), and construct rotation curves up to 3.25 T.